Education in Nuclear Science

A Status Report and Recommendations for the Beginning of the 21st Century

A Report of the

DOE/NSF Nuclear Science Advisory Committee

Subcommittee on Education

Subcommittee Members

Cornelius Beausang	University of Richmond (Yale University prior to August 2004)
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The Charge to the Subcommittee

NSAC is asked to do an assessment of how the present NSF and DOE educational investments relevant to nuclear science are being made and to identify key strategies for preparing future generations of nuclear physicists and chemists.

- Education at all levels – undergraduate, graduate student, postdoctoral – is important to NSF/DOE. Are the current investments in education optimal?
- What are the present and probable future skills and roles of nuclear scientists in the public and private sectors?
- What does the demographic picture for the future of nuclear science look like? What can we say about improving workforce diversity?

The Charge Continued
-- 2 --

Your report should document the status and effectiveness of the present educational activities, articulate the projected need for trained nuclear scientists, identify strategies for meeting these needs, and recommend possible improvements or changes in NSF and DOE practices. Your report should also identify ways in which the nuclear science community can leverage its capabilities to address areas of national need regarding K-12 education and public outreach.

Web-based Surveys

A. Ph.D.s in Nuclear Science: 5-10 years later.
B. Current postdoctoral appointees.
C. Current graduate students.
D. Current undergraduates. Survey conducted for those in REU(s). (Research Experiences for Undergraduates). Discussion at Tucson Fall 2003 DNP meeting with CEU(s). (Conference Experience for Undergraduates).

General Observations

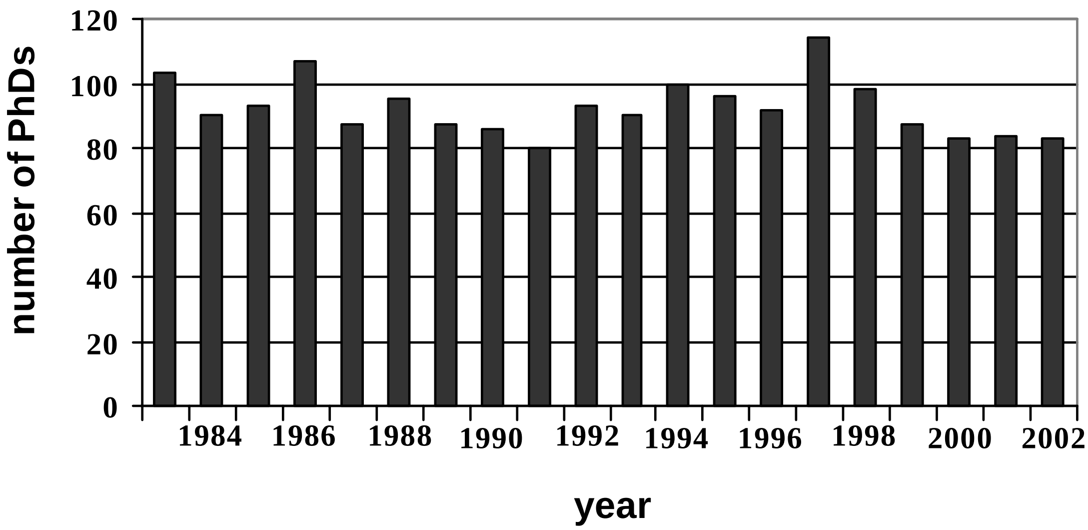
Overall, substantial satisfaction with a career in nuclear science, but accompanied by a significant fraction of really dissatisfied individuals. High level of satisfaction with many academic aspects of graduate student and postdoctoral education. Serious concerns over permanent job situation.

Some major factors leading to our recommendations

- The overall demographic situation (in a field with forefront science and exciting plans)
  - Slowly declining PhD production
  - Low, slowly increasing percentage of women
  - Abnormally low percentage of ethnic minorities
  - Too long time to “first job.”

- Inadequate career advice/job help/overall mentoring
  - Unrealistic career expectations for too many
  - Poor preparation for careers outside academe and the national labs.
  - Serious dual career couples issues.
- The major importance of undergraduate research in nuclear science in maintaining/growing the graduate student population.
- The necessity to improve K-12 and public education aspects of nuclear science and the involvement of nuclear scientists.

Data from the Survey of Earned Doctorates –1–

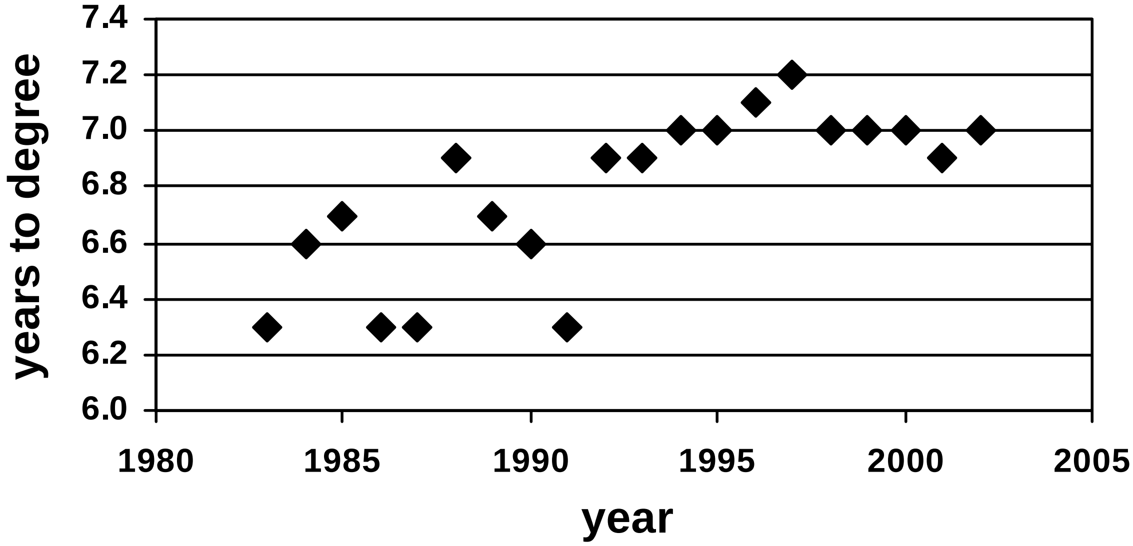


Nuclear Physics & Nuclear Chemistry
PhD's Awarded

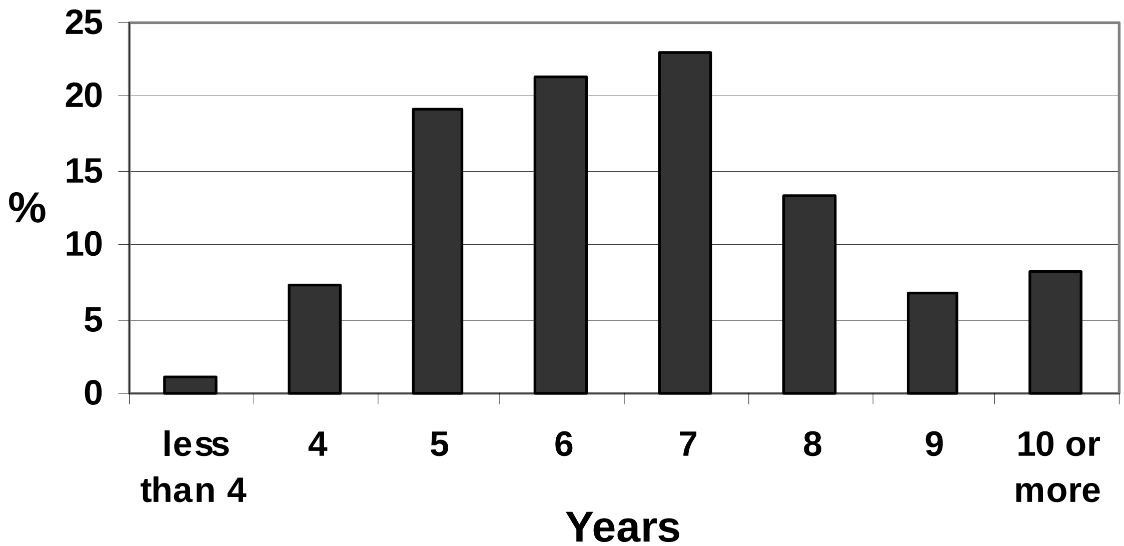
Percentage of US Ph.D.s to Non-US Citizens
3-year average (2000~2002)

	Average Ph.D.s Per Year	Non-US Citizens (Temp. Visa)	Percent
Physics and Astronomy	1346	516	38.3
Nuclear Science	83	31	37.8
Elementary Particle Physics	141	63	44.3
Chemical and Atomic/Molecular Physics	91	32	35.7
Solid State and Low-Temperature Physics	290	137	47.2
Materials Science	406	185	45.7

Data from the Survey of Earned Doctorates –2–



Mean Registered Time to Degree, Graduate School Entry to PhD



Percentage Distribution of Registered Time-to-degree for Nuclear Physics and Nuclear Chemistry doctorate recipients, 1998 - 2002

Data from the Survey of Earned Doctorates –3–

Women PhDs in Nuclear Science Compared to Other Disciplines

3 year Average (2000-2002)	Percent
•Physical Sciences	**25.3**
–Chemistry	**32.2**
–Computer Science	**18.7**
–Earth Science	**31.1**
–Mathematics	**26.9**
–Physics and Astronomy	**15.0**

6 year Average (1997-2002)	
•Nuclear Science	**14.1**

Ethnic Background of Recent US Citizen PhD's: Nuclear Science Compared to Physics and Astronomy

	Percentage			
	American Indian	Asian	Black/ African American	Hispanic
Nuclear Physics & Nuclear Chemistry (1991→2002 average, 12 years)	0.3	N.A.	1.3	1.3
Nuclear Physics & Nuclear Chemistry (2000-2002 average)	N.A.	3.3	N.A.	N.A.
Physics and Astronomy (2000-2002 average)	0.2	9.9	2.1	3.2

Enhancing the Undergraduate Experience (utilizing various surveys)

Recruitment and Retention – Maintaining the pipeline

- ❖ Undergraduate years - crucial window of time
- ❖ Key elements: Good high school physics instruction, college **course in nuclear science**, **research participation**, and **interaction** with the broader community of nuclear scientists

… at a glance

- Undergraduate nuclear physics courses in short supply
- NSF and DOE support of undergraduates crucial to NS program
- While quality and quantity of UG research experiences are evident, more active recruitment needed to retain students in NS
- Participation among under-represented groups woefully lacking

Undergraduate Courses in Nuclear Physics

The number of undergraduate courses in nuclear physics nationwide is low

- First exposure to nuclear physics (if it occurs) is commonly in graduate school
- NP courses can be difficult to offer, especially at smaller undergraduate institutions that produce nearly half of all physics bachelor's degree recipients

The table below lists the fraction of undergraduate students in the university or college sample *having access to a nuclear physics course*

Largest Bachelor's producing programs	Nuclear Physics	Nuclear/atomic or Nuclear/particle
23 PhD-granting universities	18%	43%
7 Bachelor's-granting colleges	30%	24%

An online database (not a "remote learning course") could provide useful tools and resources for departments developing their own course offerings, or integrating current and cutting-edge nuclear physics content more fully into their current offerings.

We recommend the establishment of an online nuclear science instructional materials database, for use in encouraging and enhancing the development of undergraduate nuclear science courses.

UG Research Opportunities in Nuclear Science

- ❖NSF Research Experience for Undergraduates (REU) program
- ❖NSF Research at Undergraduate Institutions (RUI) program
- ❖DOE University Research Grants
- ❖DOE Science Undergraduate Laboratory Internships (SULI)
- ❖University support

- Nuclear science community has strong tradition of active involvement of undergraduates in research
- >200 undergraduates participate in some sort of NSF/DOE/other supported nuclear science research each year
- Between 60-80 of these students participate in the CEU per year
- The fraction of these that continue on to graduate school in NS is low
- While we commend the NS community for its notable dedication to undergraduates, we nevertheless encourage a deeper commitment among our colleagues to *recruiting* promising undergraduates into nuclear science

We recommend that there be a concerted commitment by the nuclear science community to be more proactive in its recruitment of undergraduates into nuclear science, especially among underrepresented groups. We also recommend that the NSF and the DOE continue to be supportive of requests for recruitment and outreach support.

Undergraduate Surveys

- Summer 2003 REU participants (165 total respondents)
  - Male (52%) and female (48%) respondents were well balanced
  - Students from primarily Black- or Hispanic-serving institutions were very low (approximately 1% of the total for each), likely reflecting the low REU participation rate of these groups
- REU program directors e-mail query
  - Directors from 11 REU sites responded with data comparing size of the applicant pool with number of final participants
  - In majority of programs applicants far outnumbered accepted participants, indicating competitive programs
- Fall 2003 CEU participants (44 respondents – 68% of pool)
  - Men (73%) and women (27%) were fairly representative of CEU participation
  - 35% derived from REU programs, 19% from other NSF (e.g., RUI) grants, 31% from DOE supported research programs, 8% from university support, and 7% unknown

REU and CEU - graduate school plans and nuclear science

❖ REU survey participants:

- 65% of REU survey participants had graduate school plans prior to REU
- 25% reported that the experience *increased* their interest in graduate school

❖ CEU survey participants:

- 77% of CEU survey participants plan graduate school in physics or chemistry
- Fully 90% reported that the CEU experience *increased* their interest in nuclear science
- 40% reported they would definitely or probably pursue nuclear science in grad school - an additional 40% were not sure but would consider it

We strongly endorse the important role that the NSF REU and RUI programs and DOE university research grant support has played in motivating and training young scientists in nuclear science, as well as their support of the CEU program, which gives undergraduate students a venue for presenting research to and interacting with the professional community.

We recommend that the NSF and the DOE continue supporting research mentorship opportunities in nuclear science for undergraduate students through programs and research grant support. Additionally, we recommend that they consider expanding support if proposals for undergraduate student involvement in nuclear science research increase.

Heighten Awareness of Undergraduate Issues

Given the importance of recruiting and retaining undergraduates in nuclear science, critical as they are to the future health and vitality of nuclear science:

> We believe that an appropriate mechanism that will serve to heighten community awareness of the undergraduate issues discussed above should be created
>
> It would publicly acknowledge and celebrate exceptional examples of undergraduate involvement and mentoring

We recommend that the Division of Nuclear Physics of the American Physical Society consider the establishment of a community-developed recognition award for individuals providing research opportunities and/or mentoring to undergraduates in nuclear science.

Nuclear Chemistry Summer School

- ❖ Sponsored by DOE's Office of Basic Energy Sciences and Office of Biological and Environmental Research
- ❖ Two sites located at San Jose State University in California, and Brookhaven Laboratory in New York – limited to 12 students each
- ❖ Applicants have grown from ~40 (1999) to > 100 (2004)

Approximately 70% of participants go on to physics or chemistry graduate school, most of whom concentrate on nuclear chemistry or radiochemistry

Current production rate of nuclear chemists is low – 10 per year compared with 40 per year in 1970

Recruitment into and training of young scientists in the field of nuclear and radiochemistry remains a very high priority for the nuclear science community.

Should the number of applicants to the summer school continue to increase:

We recommend the establishment of a third summer school for nuclear chemistry, modeled largely after the two existing schools.

Response Rates of the Comprehensive Web Surveys

	Graduate Students	Postdoctoral Fellows	PhD’s 5-10 Years Later
Survey Population	627	352	412 (with known e-mail addresses)
Respondents	353	225	251
Response Rate	56%	64%	61%

AIP response rate 2001 graduate student report 39%
Golde and Dore study 2001, doctoral students in 11 fields at 27 universities 42.5%.

The Representation of Women in these Surveys

Graduate Students	Postdoctoral Fellows	PhDs 5-10 Years Later (7/1/92-6/30/98)
20%	14%	12%

The Female/Male ratios are essentially independent of citizenship status.

Graduate Student Web Survey

A Web based Survey of Nuclear Physics and Nuclear Chemistry Graduate Students

<u>627</u> Contacted (Dec. 2003 – Mar. 2004)

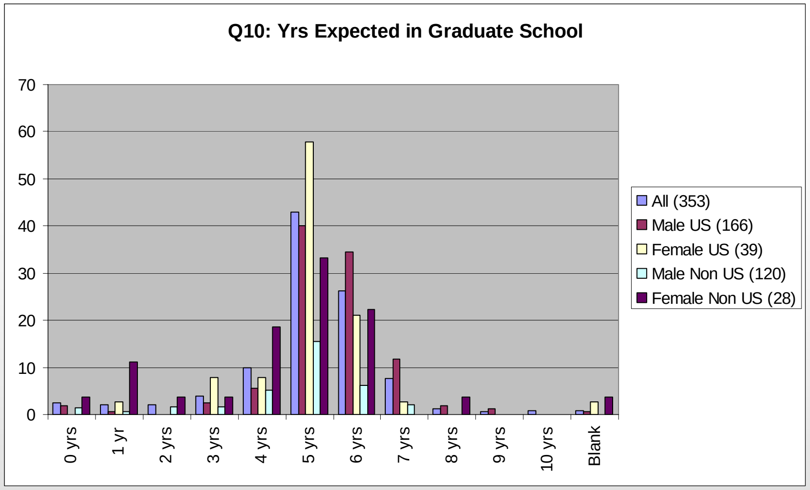
<u>353</u> Responses

<u>56%</u> Response Rate

<u>Total of 93 questions</u>

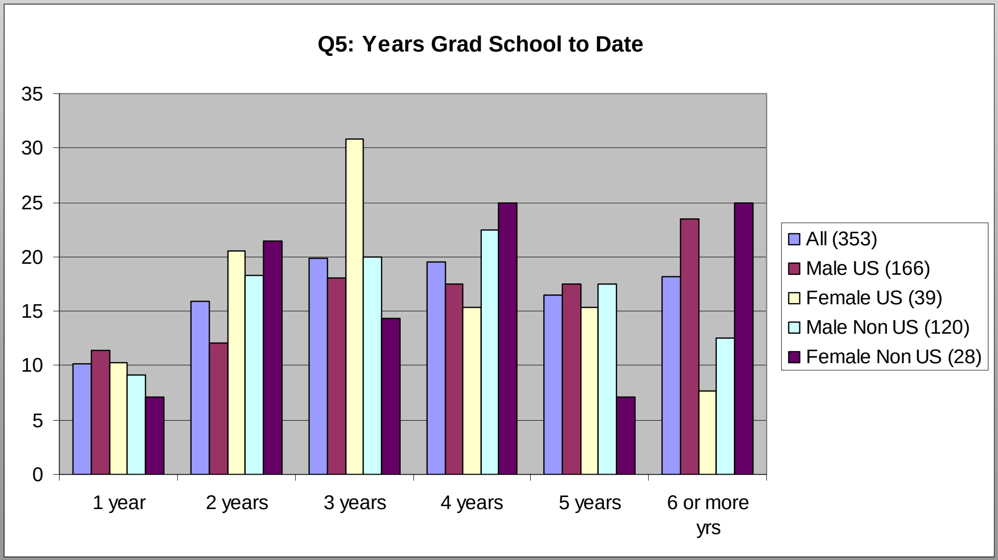
Time in Graduate School

… Most students expect to spend between 5 & 6 years in grad school …



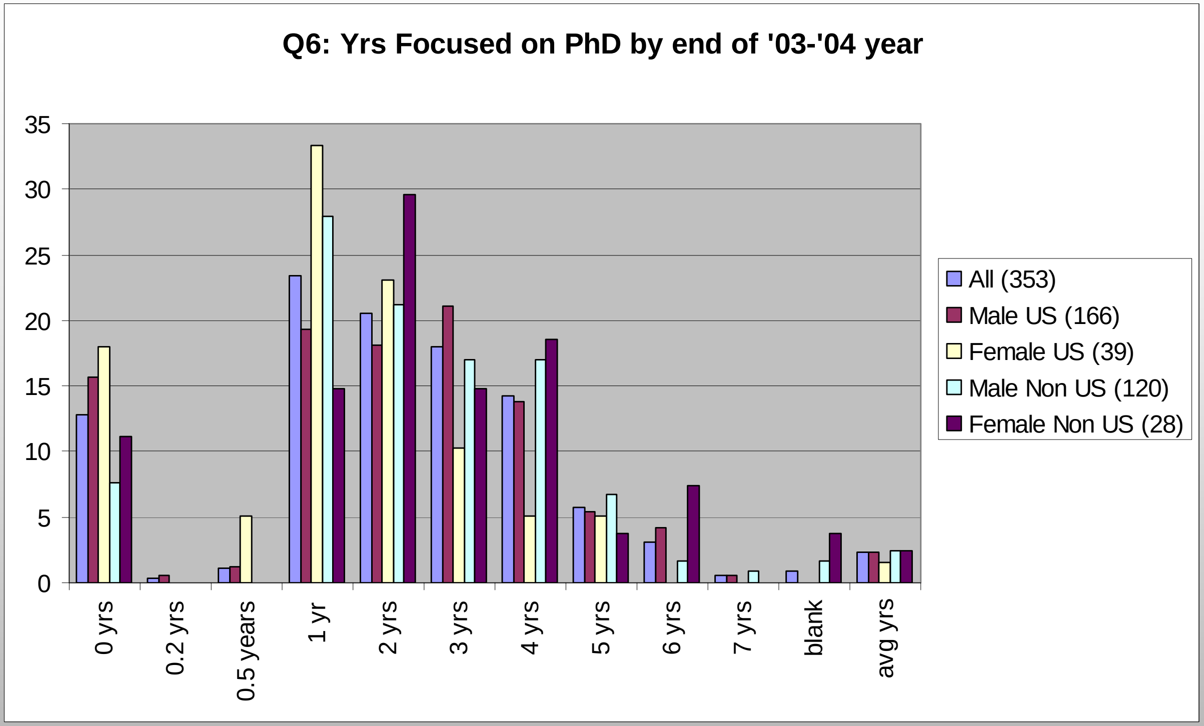
Q10: How many years do you expect to spend in graduate school?

18% have already spent 6 or more years in graduate school



Q5: By the end of the '03-'04 academic year, how many years of graduate study will you have completed?

Time in Graduate School



Q6: How many of these years will you have been primarily focused on your Ph.D. research?

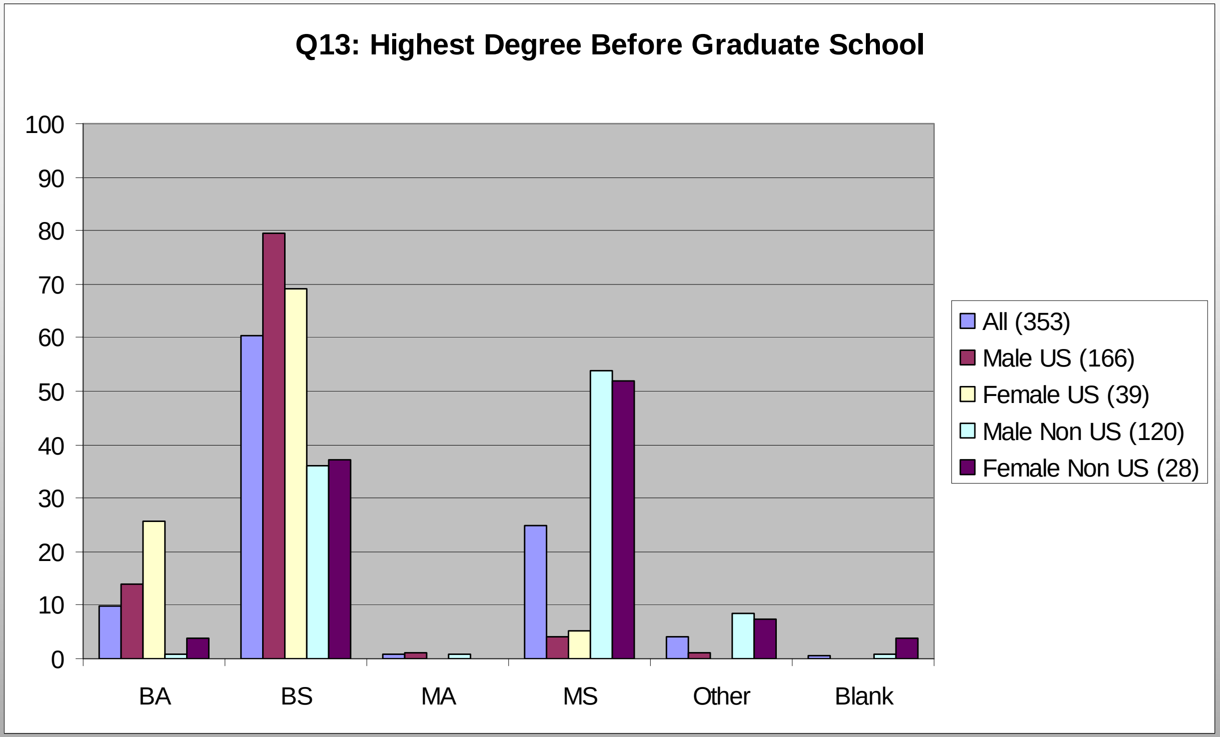
~9% have spend 5 or more years already primarily focused on research

The average time to degree is too long!

Undergraduate Preparation for Graduate School

~ All US citizens started grad school after a BS or BA.

…only ~5% had a prior masters degree.



Q13: My highest degree before graduate school was:

In contrast about 60% of foreign students had already completed a masters before commencing graduate study in the US.

Other Graduate Student Survey Results:

- Most students had some form of undergraduate research experience: ~ 85% US, ~ 75% foreign
- Attracted to nuclear science by interactions with the faculty, good undergraduate or summer research experience, small research groups
- US graduate students in nuclear science consistently ranked themselves lower than their foreign counterparts, both in terms of their undergraduate preparation for graduate school and in terms of their class ranking in graduate school.
- For their career, 40% want to go to academe; 25% to national laboratories; 5% to industry and 30% are undecided

Postdoctoral Fellow Web Survey

<u>352</u> Contacted (Feb. 15 – Mar. 15, 2004)

<u>225</u> Responses

<u>64%</u> Response Rate

<u>47%</u> US PhD <u>53%</u> Non-US PhD

The quality of advanced training in nuclear science brings many foreign postdocs to the US.

Current Career Goals of Postdoctoral Fellows

Goals	Percentage
Academic or national laboratory researcher	51
To be a professor	34
Researcher in BGN	4
Administrator/manager	1
Start a business	1
No formulated goal	4
Other	5

Family and Career:
Spouse's Education

Currently married or in a committed relationship:

Women	Men
N = 19/29 (66%)	N = 121/166 (73%)

Spouse/Partner's Education

	Women	Men
Bachelor	0%	30%
Master's	22%	38%
Doctorate, MD, JD	78%	30%
Other	0%	2%

What is the field of your spouse's/partner's education?

	Women (23)	**Men** (142)
Nuclear Science	57%	10%
Other Natural Science	17%	17%
Education	0%	9%
Engineering	9%	13%
Fine Arts	4%	3%
Humanities	4%	9%
Social or Behavioral Science	0%	8%
Business Management	0%	9%
Law	0%	4%
Medicine	4%	14%
Other	5%	4%

43% of postdocs indicated that family issues affected their careers or those of their spouses or partners

The top four reasons given to explain how family issues had affected careers were:

My career was compromised in order to find two positions together	38%
My spouse's career was compromised in order to find two positions together	35%
My spouse gave up his/her career to care for children	13%
Our relationship was damaged/destroyed because we could not find two positions together	7%

Other Postdoctoral Survey Results

- The average annual postdoctoral salary was \$44.5 k
- 91% of the men and 80% of the women had employer paid health insurance
- 75% of the men and 67% of the women had employer paid dental insurance

What advice would you give beginning graduate students in nuclear science?

Learn/develop/broaden your skills as much as possible; work hard; be the best.	24%
Learn about/plan now for a career outside nuclear science and investigate all the possibilities.	17%
Look at the long-term prospects/lifestyle and decide if you really want it and really like it.	13%
Choose your advisor/topic carefully; work for someone you respect and who respects you.	8%

Nuclear Science Ph.D.s 5-10 Years Later (7/1/92 – 6/30/98)

<u>412</u> Contacted (Dec. 15 – May 4, 2004)

<u>251</u> Responses

<u>61%</u> Response Rate

Mean age <u>38.5 years</u>

Percent women <u>12</u> (same as the survey population)

Will cover:

- The (Completed) Postdoc Experience
- Entry Into the Job Market and Current Job

Number of Postdoctoral Positions & Average Total Time in Postdoctoral Positions

Postdoctoral Appointments	Biochemistry (86%)		Mathematics (31%)		Nuclear Science (70%)	
	Percent	Mean Total Years	Percent	Mean Total Years	Percent	Mean Total Years
One	60	3.0	60	1.8	61	2.3
Two	31	4.5	29	3.1	32	4.5
Three	7	6.9	8	4.7	6	5.9
Four	1	8.5	3	6.8	1	7.9
Five	1	--	0	--	0	--

Postdoctoral Appointments By Gender

	Male	Female
% doing postdocs	70	67
Average # of postdocs	1.5	1.5
Mean years spent in postdocs	3.3	2.7

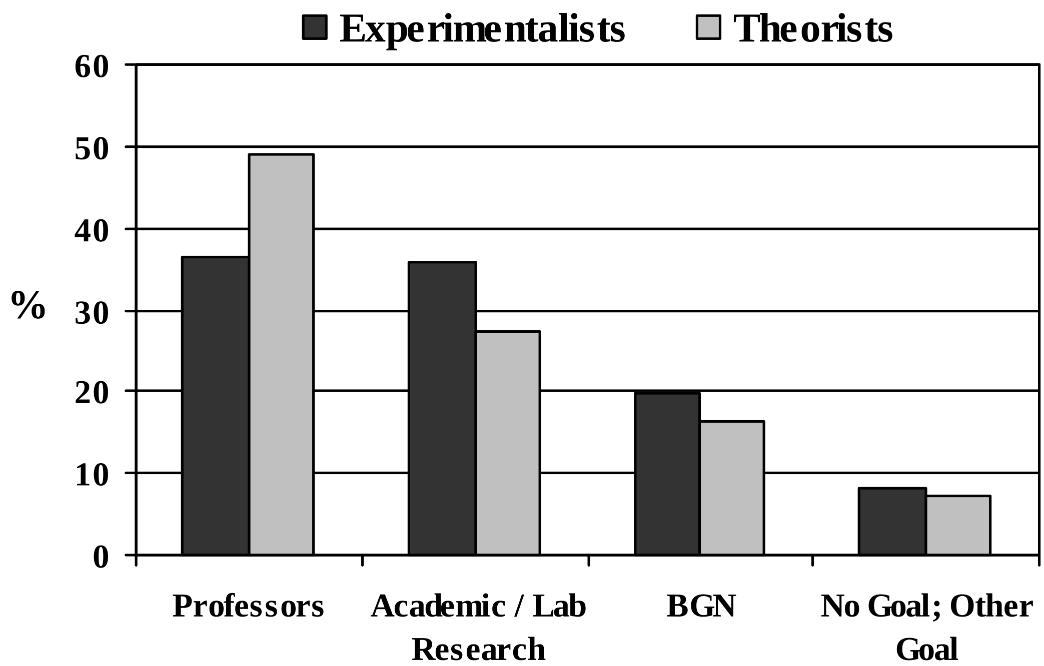
Environment for first and second postdoctoral positions, for nuclear science Ph.D.'s

Environment	First Postdoc	Second Postdoc
University	50%	48%
National Lab	39%	33%
Business/Industry	0%	0%
Government	1%	2%
Medical School/Hospital	3%	2%
Other Nonprofit Organization	1%	0%
Outside U.S.	7%	15%

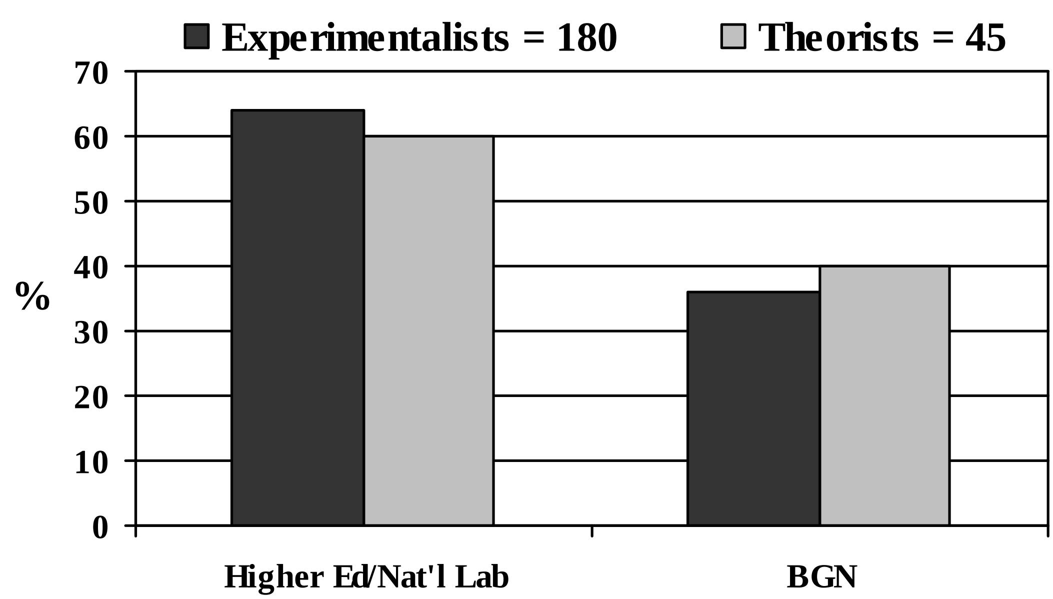
Major Factors in the Choice of First and Last Postdoctoral Positions, for Biochemistry and Nuclear Science Ph.D.'s

	Biochemistry		Nuclear Science	
Reason	**First Postdoc**	**Last Postdoc**	**First Postdoc**	**Last Postdoc**
Necessary step	75%	55%	73%	58%
Training in another subfield or area	42%	44%	21%	18%
Additional training in subfield	38%	18%	40%	24%
Work with a specific person	32%	36%	15%	21%
Only acceptable employment	10%	22%	27%	21%

Multiple answers were permitted



Career goals for experimentalists (78%) and theorists (22%), at the conclusion of graduate school



Current Employment Sector (May 2004): Experimentalists & Theorists

Job titles at the time of the survey, as reported by respondents. Individuals who were still postdocs are not included here.

* Some did not respond about current job titles	Experimentalists N = 178*		Theorists N = 44*	
	N	Percent	N	Percent
Faculty (tenured and tenure-track)	46	26	11	25
Non-tenure track faculty	8	4	7	16
National laboratory researcher	44	25	7	16
Other academic/national lab	15	8	1	2
BGN	65	37	18	41

When asked whether their current job in academe or the national labs was in nuclear science, only 36% said yes.

Current job titles of respondents employed in business, government, or the nonprofit sector. The numbers indicate numbers of responses

- Science or Engineering R&D (not nuclear, not medical) (17)
- Software Engineer (11)
- Finance (8)
- Nuclear Science R&D (6)
- Medical Instrumentation R&D (5)
- Radiation Physics / Medical Physics (5)
- Top Executive (CEO, COO, CFO) (4)
- General Management (3)
- Manufacturing/Engineering/Management Information Systems (3)
- High School Teaching (3)
- Technical Support (3)
- Consulting (2)
- Legal (2)
- Small Business Owner (2)
- Other (6)

Total 80

Faculty expectations regarding professional careers. Survey participants were permitted multiple responses.

	N	Percent of Respondents* (N =234)
Faculty encouraged pursuit of academic careers at research universities	148	63
Faculty encouraged pursuit of academic careers at 4-year colleges	45	19
Faculty encouraged pursuit of national laboratory careers	101	43
Faculty encouraged pursuit of careers in BGN sector	28	12
Faculty did not have specific expectations about career choices	95	41

* Respondents chose all that applied

A quotation from Roman Czujko, Director of the Statistical Research Center of the American Institute of Physics, March 2001:

> Physics departments are isolated from the world outside of academe. Many physics departments are still driven by the dominant goal of adding to the knowledge base, that is, conducting basic research and preparing students to become the next generation of basic researchers. Too few faculty understand the remarkable diversity of careers commonly pursued by people with physics degrees. Too few departments have modified their curriculum to address the needs of the majority of their students, that is, those students who do not become Ph.D.'s conducting basic research.

Respondents' advice to beginning doctoral students

Open-Ended Questions: Most Cited of 171 Responses		
	N	**Percent**
Strongly reconsider a Ph.D. in nuclear physics	41	24
Continue only if you "love" it*	18	
Don't/Choose alternative field/Bad job market	23	
Be interdisciplinary/breadth	23	13
Focus/define your goals	17	10
Work hard	16	9
Keep options open/flexibility	16	9

* Job market-related

"If you don't absolutely love this stuff, do something else. Academic research is all about sacrifice. You'll work less and find more job openings, money, flexibility, etc. doing just about anything else."

"Quit and do something else. If you are smart enough for nuclear physics, you can find something else that will give you a much better life."

"I would advise students that there is not a sure path from the Ph.D. to a faculty job at a major university or lab, even for the very qualified."

Respondents' recommendations for doctoral programs

Open-Ended Questions: Most Cited of 152 Responses		
	N	**Percent**
Provide career planning and guidance, especially about BGN	34	22
Work for breadth and interdisciplinary skills	20	13
Develop skills that the marketplace needs	18	12
Improve image of field/keep current/be active	11	7
Better mentoring and advising; address individual needs/goals	11	7
Shorten the time to the Ph.D.	10	7
Honesty/realism about the job market	8	5

"Provide better guidance/contacts for non-academic career paths. This requires that the Ph.D. advisers do a little extra work here."

"Better and earlier advice on career paths and positions."

"Many students seem to feel that if they get a Ph.D. but do not go on to a university or national lab job then they have failed. It would be good to try to change this culture."

Other Ph.D.s 5-10 Years Later Results

Percentage of experimentalists and theorists in different jobs who felt that getting a Ph.D. was definitely or probably worth the effort

	Experimentalists		**Theorists**	
Current Job	N	Percent	N	Percent
Tenured / Tenure-Track	42	91	11	100
National Lab	40	98	5	100
BGN	51	84	18	100

- 58% would get a Ph.D. in nuclear science again, while 17% would choose another subfield of physics or chemistry. Another 13% would get a Ph.D. in another field and 12% would get a M.D., J.D. or no degree at all.
- The quality of the graduate research experience was rated very highly, with 52% viewing it as “excellent” and 33% as “good.”
- More than 90% of the survey respondents felt that communication skills, collaboration, and team work were either “very important” or “fairly important” in doctoral education. Also, more than 80% thought that interdisciplinary research and organization skills were important.

Observation

Though we can infer that the respondents felt that their doctoral education had prepared them to be effective in their current jobs, it is clear that proper career advising has not taken place.

Enhancing Graduate Student and Postdoctoral Education

Challenges

Continuing to attract some of the best undergraduates and beginning graduate students into careers in nuclear science

Preparing graduate students and postdocs for careers in a wide variety of jobs for nuclear scientists – in universities, national laboratories, and business (industry), government and non-profit organizations

Reducing the time to the first job

Working to create a culture of inclusion, that actively promotes effective outreach to women and members of traditionally underrepresented groups

To attract some of the best undergraduates and graduate students into nuclear science

We strongly endorse the Secretary of Energy Advisory Board's 2003 recommendation that new, prestigious graduate student fellowships be developed by the Office of Science in the areas of physical sciences, including nuclear science, that are critical to the missions of the DOE.

We also strongly endorse the accompanying recommendation that new training grant opportunities in nuclear science be established.

Prestigious fellowships and training grants would serve to attract the brightest graduate students for study in the physical sciences, including nuclear science, in areas critical to the missions of the DOE, providing them with the flexibility to prepare for research in their subfield of choice.

To recognize nuclear scientists early in their careers for their accomplishments and potential, and to help increase the visibility of nuclear science

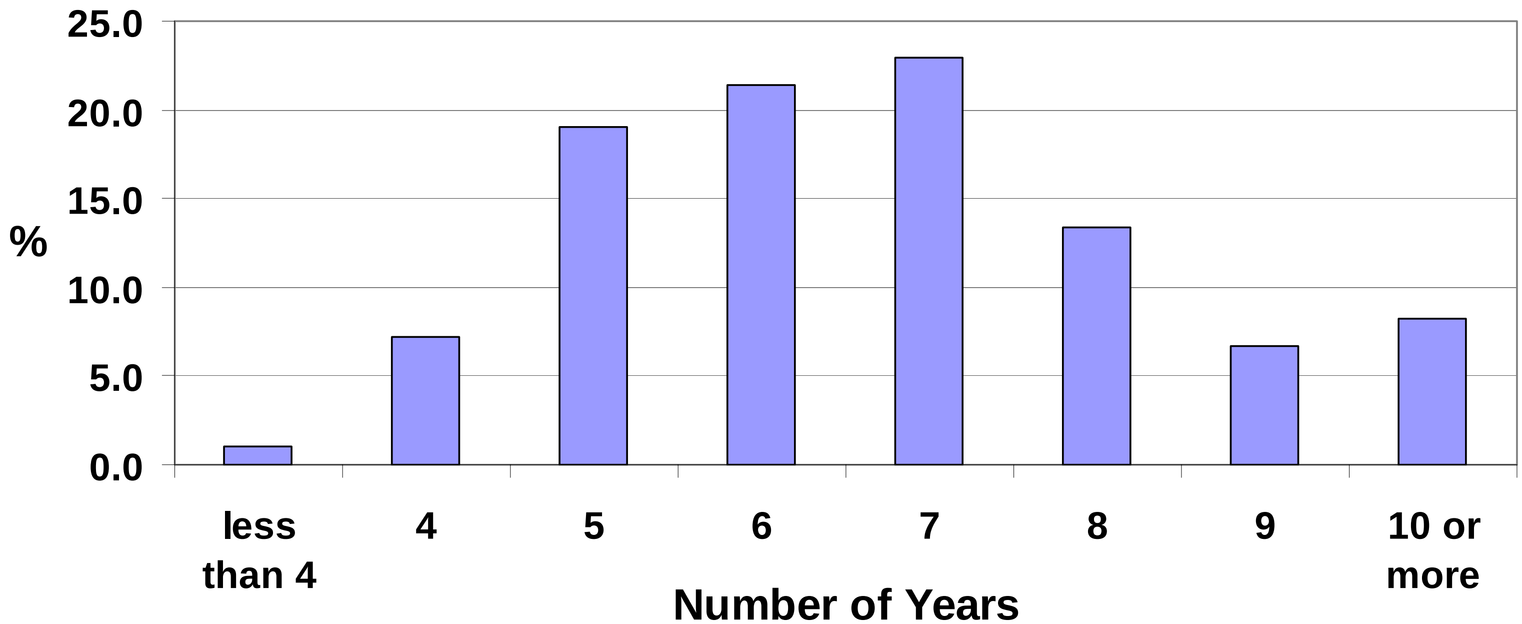
We recommend that prestigious postdoctoral fellowships in nuclear science be established, with funding from the NSF and the DOE.

There are relatively few ways in which nuclear scientists early in their careers are recognized for their accomplishments and potential, and even fewer ways in which this recognition extends beyond the nuclear science community. Prestigious postdoctoral awards in other physical sciences have served to meet both of these challenges.

The establishment of prestigious postdoctoral positions would also support a recommendation of the NSAC theory subcommittee.

The Need to Reduce the Time to the First Job

Percentage Distribution of Registered Time-to-degree for Nuclear Physics and Nuclear Chemistry doctorate recipients, 1998 – 2002



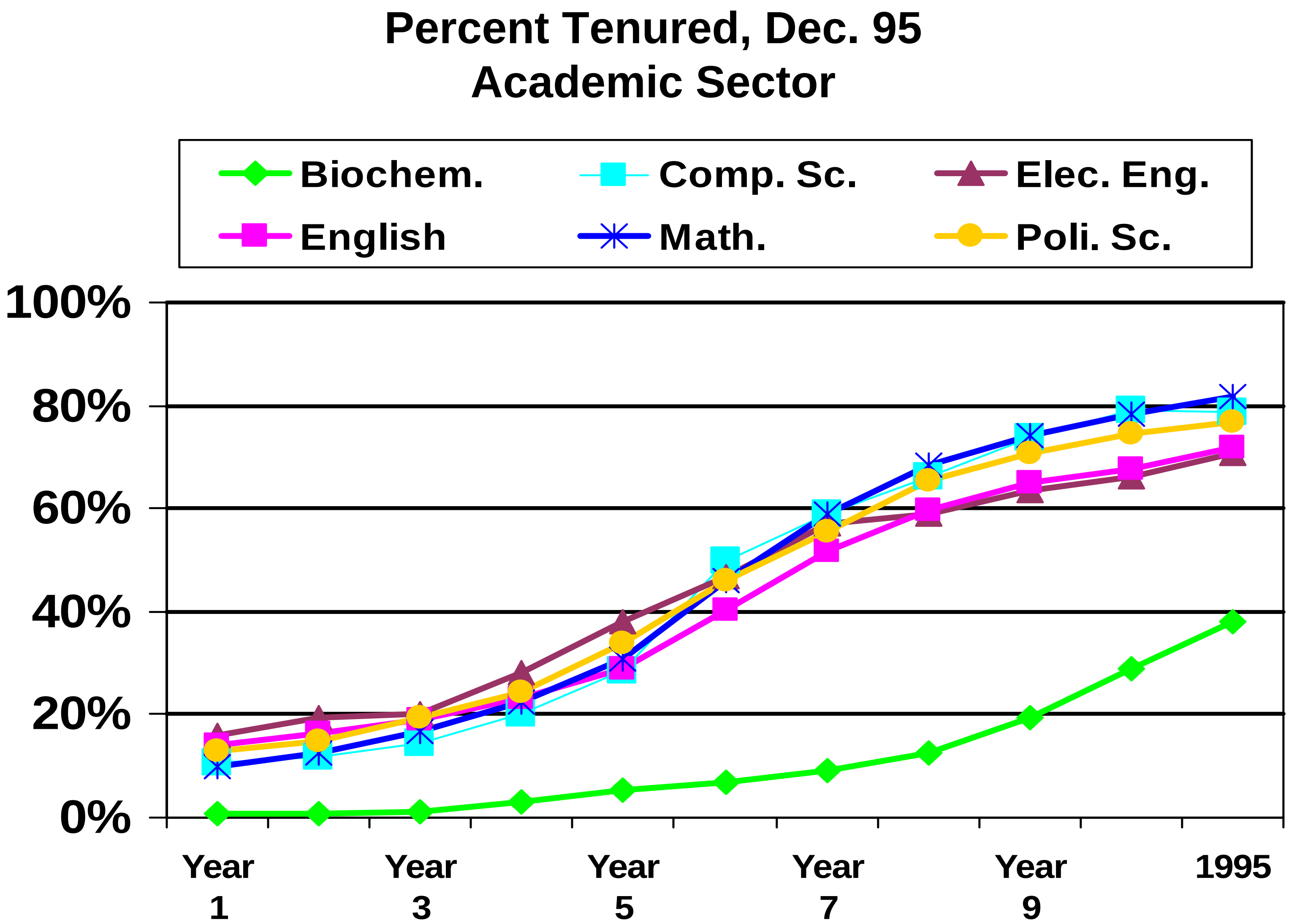
- Median time to degree in nuclear science is 7 years
- About 70% of PhDs take at least one postdoc
  - On average 3.3 years as postdoc
- Time to independent career > 10 years, very long

The Need to Reduce the Time to the First Job

Concern across the US
All science fields

- National Academy of Sciences, Committee on Science, Education, and Public Policy (COSEPUP)
  - Revitalize PhD programs in science & engineering
    - Broader range of options
    - Shorten time to degree
  - Enhance postdoctoral experience
    - Set time limits for total time in postdoc positions
    - Career guidance and professional development
- APS/AAPT Physics Department Chairs
  - Decrease time to PhD
  - Funding agencies: encourage timely completion of degrees

The Need to Reduce the Time to the First Job



Conclusion

We believe that the median time to the PhD should be shortened to five and a half or six years. Therefore,

We recommend that the nuclear science community assume greater responsibility for shortening the median time to the PhD degree.

The following activities should be among those considered to realize this goal:

- Nuclear science faculty should conscientiously monitor the progress of their graduate students toward the Ph.D. degree.
- Recognizing that a high-quality Ph.D. program contains, in addition to research, various scholarly components such as coursework, qualifying examinations, and in some cases serving as a teaching assistant, nuclear science faculty should work with their departmental colleagues to optimize these components for their students' education. In doing this, individual graduate students' needs and goals should be taken into account.

Conclusion (continued)

- Nuclear science faculty should identify new ways to engage graduate students in research early in their graduate careers.
- The funding agencies should be apprised of graduate students' progress in their research and toward their degrees, and work to help faculty toward the goal of optimizing the educational experience and reducing the time to completion of the Ph.D. degree. Monitoring the placement of graduate students after their Ph.D. work, as well as the attrition of those who do not finish, will also provide important data to improve overall graduate student education.

Enhancing Diversity

A Bleak Current Picture

- Women
  - 10% of physics faculty, up from 6% in 1994
  - 20% of recent tenure-track hires in nuclear science
  - Participation drops dramatically from high school to undergraduate majors to Ph.D.'s

- Ethnic minorities
  - About 4% total of physics faculty are African American or Hispanic
  - Among U.S. citizens, 8% of bachelor's and 5% of Ph.D.'s are awarded to these groups
  - Again, participation drops at every educational step
  - Nuclear science doing as poorly as physics generally

Enhancing Diversity

Impediments to Improvement

- Disparities in family income and debt burden among ethnic groups

- Differences in parents’ educational attainments

- A scarcity of mentors, for both women and ethnic minorities

Enhancing Diversity

Impediments to Improvement: Family Matters

- Lack of accommodation for women with children

- Dual-career issues: Results from our surveys
  - 100% of female postdocs' partners had advanced degrees (68% for men)
  - For recent Ph.D.'s, similar results: women, 82%; men, 57%
  - Partners of female postdocs are likely to be nuclear scientists also (57% for women, 10% for men)

- Dual-career conflicts affect women disproportionately

Enhancing Diversity

Encouraging Full Participation

- **We recommend that there be a concerted commitment by the nuclear science community to enhance the participation, in nuclear science, of women and people from traditionally underrepresented backgrounds, and that the agencies help provide the support to facilitate this enhanced participation.**

  - Enhance connections with institutions that serve minorities

  - Establish “bridge” programs

  - Adopt policies that recognize family responsibilities

  - Enhance the visibility in nuclear science of underrepresented minorities

Mentoring and Professional Development

- Effective mentoring including realistic career advice is critical to preparing all nuclear scientists for the future. This is particularly true for members of underrepresented groups, who face significant barriers to success in nuclear science research and education.

- Unfortunately, the high expectations (about 75% of respondents) of a career in academe or the national laboratories for both experimentalists and theorists is in direct conflict with the reality of the “traditional job market” for physics (or nuclear science), in which one-third to one-half of the Ph.D.’s ultimately work outside physics (or nuclear science). In fact, only 70 of 195 respondents (36%) reported a current job in nuclear science in academe or the national laboratories. The respondents whose jobs are outside of “academic” nuclear science represent an important national resource with its concomitant transfer of knowledge and techniques, but require realistic career advising beginning early in their graduate programs.

Examples of the Need for Improved Mentoring

What would have helped you with your first job search as you completed your Ph.D. or postdoctoral position?

“It would have helped to talk to other women who had been through the same process. At the time I did not know how to respond to remarks from the faculty that were interviewing me such as:

‘What’s a pretty girl like you going to do for fun in a place like this? Or

‘How many children do you plan to have? You look like you’d probably have about three.’

If I had realized this was going to happen, I would have been much better prepared. (There were no questions of this type at the interview for the job I eventually took).

“My Ph.D. advisor was completely out of the loop in terms of his/her ability to recommend alternatives to traditional nuclear science postdocs. Many of my peers in nuclear science were taking multiple postdocs; I was not interested in extending my postdoctoral experience beyond three years, so I became interested in postdoc opportunities outside of my field. (w)

Even a vague understanding of the number of applications every university receives for a single tenure-track position, and what is really needed to even be in the running. (m)

Enhancing Diversity

Promoting Professional Development

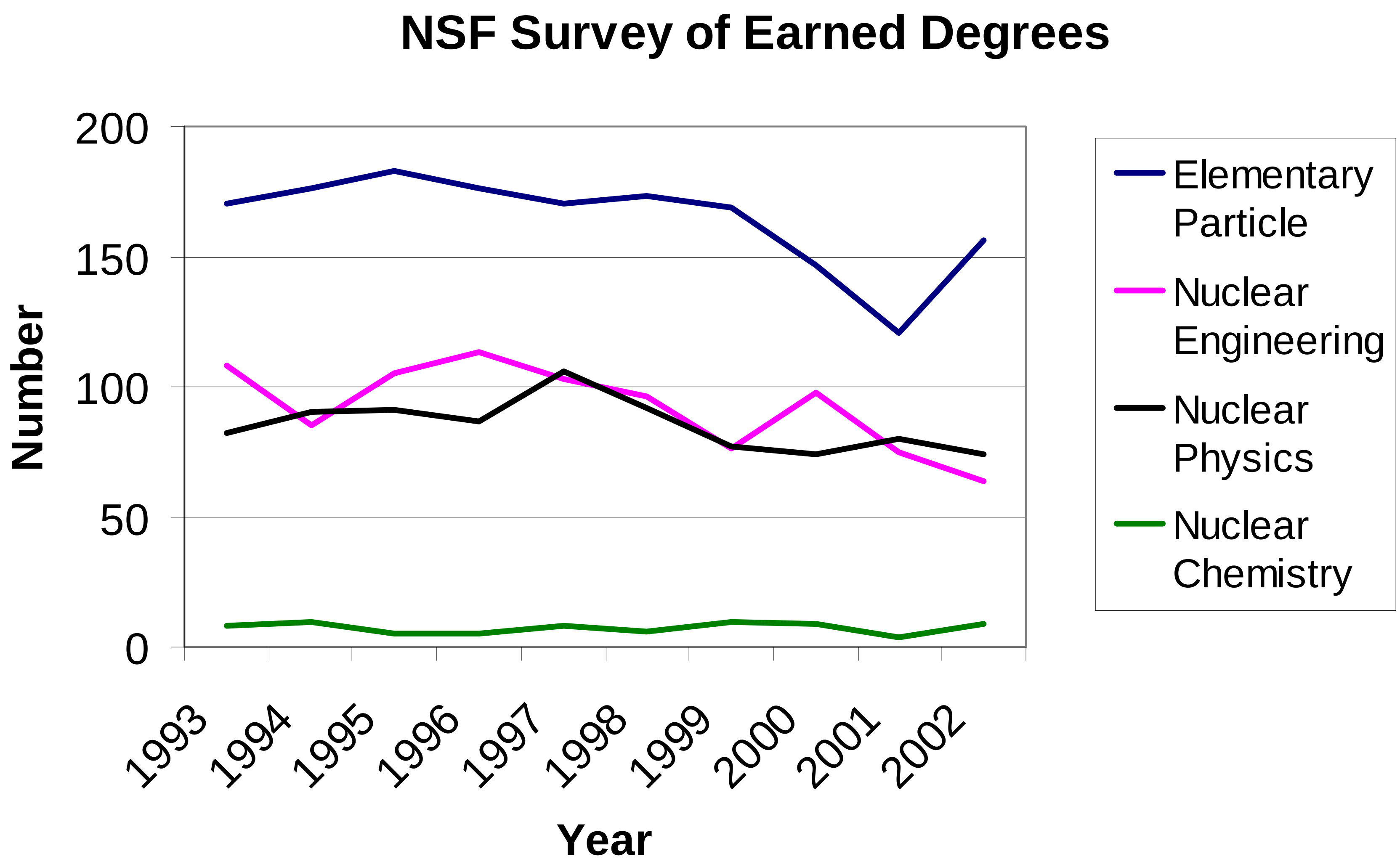
- **We recommend that there be a concerted commitment by the nuclear science community to establish mentoring and professional development programs, and that the agencies support such efforts through the funding of competitive proposals.**

  - Develop programs at professional meetings, such as the annual DNP meeting, and at the national laboratories that provide career guidance and professional development opportunities.

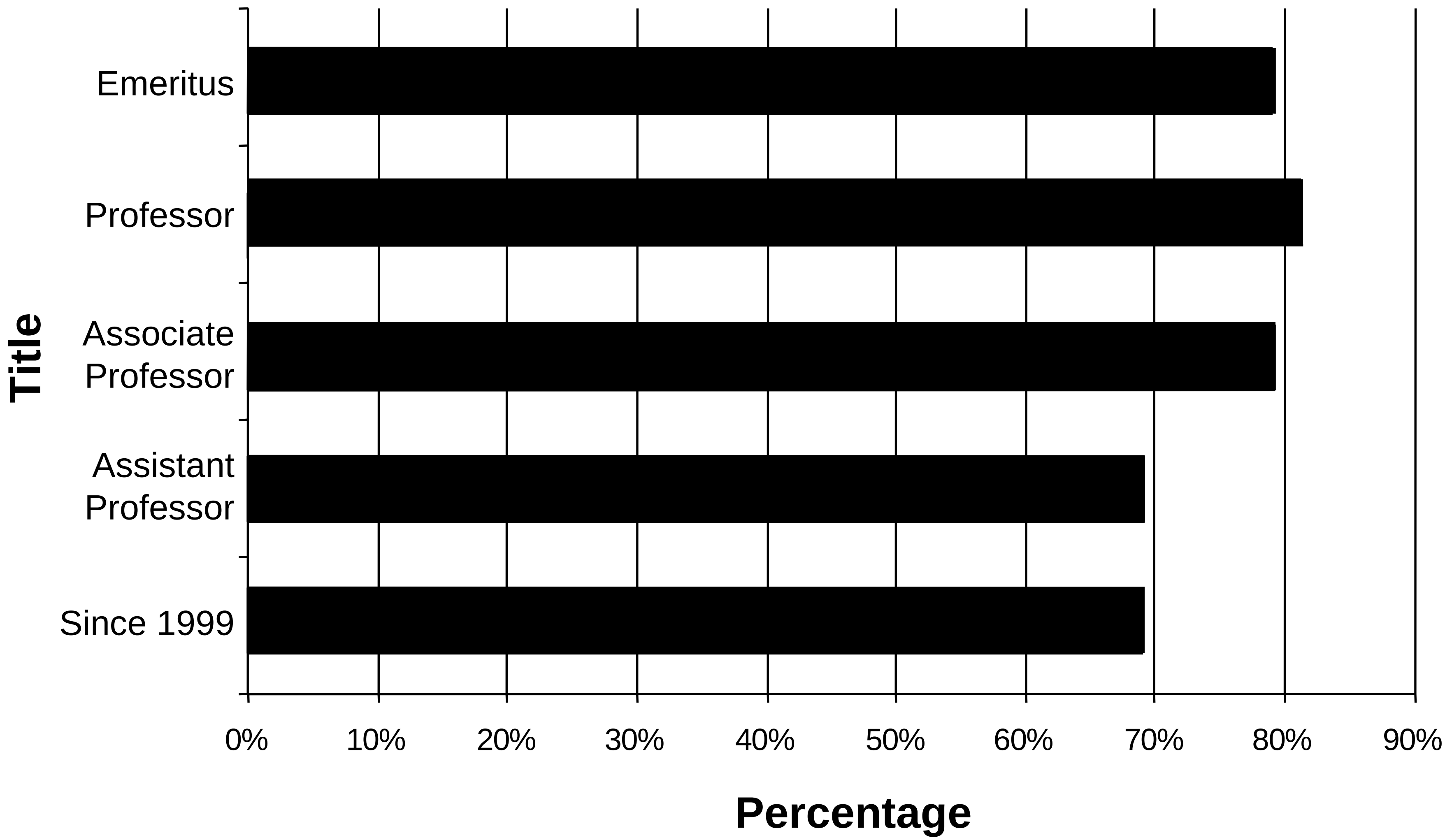
  - Enhance mentoring and advising of undergraduates and graduate students and postdoctoral scholars, especially those from underrepresented groups.

Nuclear Science Demographics

- Currently producing about 85 nuclear physicists plus nuclear chemists per year.
- Fewer than half of these will work in basic nuclear science within academia or the national laboratories
- Within ten years, 75% of the nuclear engineering and related national lab workforce will be eligible for retirement
- Increasing demand for nuclear scientists in medical physics, nuclear medicine and national security



There has been a decline by 10 to 20% in the number of nuclear scientists since the mid 1990s.



Percent of tenure-track faculty who received their Ph.D.'s from U.S. institutions

Nuclear science expertise is viewed as vital. Independent evaluations have stated that demand may exceed the supply.

We further recommend that training grants be established in areas required to advance DOE’s mission in the future, but for which the U.S. is not producing scientists and engineers. Some of these should be in traditional areas essentially unique to DOE such as nuclear engineering and nuclear science. Others will be especially useful in emerging areas like nanotechnology and biological engineering that must grow at the intersections of traditional disciplines.

Secretary of Energy Advisory Board (2003)

“In preparing Indicators 2004, we have observed a troubling decline in the number of U.S. citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering (S&E) training continues to grow. Our recently published report entitled The Science and Engineering Workforce/Realizing America's Potential (NSB 03-69, 2003) comes to a similar conclusion. These trends threaten the economic welfare and security of our country. … Now, preparation of the S&E workforce is a vital arena for national competitiveness.”

National Science Board, Science and Engineering Indicators—2004

Future Hiring

• We project approximately 40 basic nuclear science research positions per year over the next 10 years. The division directors from the National Labs estimated hiring 20 nuclear science PhDs per year over the next ten years. Tenure track demographics indicated 15 hires/years in academic ranks. Research faculty will account for another 5 hires/year.

• There is a documented looming shortage of radiochemists and nuclear engineers. Additional demands will come from homeland security and are present in medical physics.

• Long-term trends (supported by the 5 to 10 years after PhD survey) indicate that approximately 60% of these PhDs will eventually work outside academic nuclear physics. Hence the base need to support the nuclear science enterprise is 100 PhDs (40/0.4) per year. Current production is ~ 85 PhDs per year.

• Approximately 20% of the current graduating class can be expected to leave the US. This is partially compensated by non-US PhD hires for US positions.

Conclusion

We recommend that the nuclear science community work to increase the number of new PhD's in nuclear science by approximately 20% over the next five to ten years.

This recommendation can be realized without additional funding from the DOE Office of Science or the NSF Division of Physics.

•Shorten the time students spend in the PhD program.

•Become aware of, and take advantage of, funding opportunities for graduate students in areas of national need – opportunities outside the NSF Division of Physics and the DOE Office of Science.

•Encourage the best and the brightest undergraduate physics and chemistry majors to take advantage of undergraduate research opportunities in nuclear science, then actively recruit these experienced undergraduates to continue their nuclear science studies and research as graduate students.

Outreach to K-12 and Public Education

Part of the charge to NSAC: *Your report should also identify ways in which the nuclear science community can leverage its capabilities to address areas of national need regarding K-12 education and public outreach.*

The recommendation from the NSAC Subcommittee on Education: **We recommend that the highest priority for new investment in education be the creation by the DOE and the NSF of a Center for Nuclear Science Outreach.**

Center for Nuclear Science Outreach: *Motivations*

- Public misconceptions hamper our field
  - The “nuclear” problem
  - The “radiation” problem
- Effective outreach can engage the public from K-12 to adult
  - e.g., space sciences, the genome project
- Effective outreach specifically focused on K-12 students is critical to increasing the diversity of nuclear scientists.
- Stimulate an increasing national understanding of the nuclear world that Mankind lives in, as well as an improved appreciation of the goals and achievements of nuclear science
- Create a dedicated resource, to be consistently focused on developing communication and outreach on nuclear issues

Center for Nuclear Science Outreach: *Efforts by Others*

- Many efforts by organizations, national labs, interested groups, etc.
- Resources are available, but the message is normally focused locally, rather than nationally
- The Center would profit from these other efforts, but achieve its outreach goals while strengthening and supporting these existing efforts, not duplicating them

Reasons for Outreach by the Nuclear Physics European Collaboration Committee:

- *Cultural reasons* – Nuclear science is an important part of our cultural heritage; it contributes to answering fundamental questions about the structure of matter, the birth and fate of our universe, and the origin of life in the cosmos. It is relevant to our understanding of the environment and the place humankind occupies in nature.
- *Economic reasons* – Technology and innovation are created through science, and that includes nuclear science. Such progress plays an important role in creating wealth and provides one of the driving forces in our society.
- *Sociopolitical reasons* – Scientific literacy among the public is essential as a foundation for rational choices in the intelligent uses of technology. Understanding and communicating the benefits as well as the risks of our modern technologies is a vital component of an advanced society.

Center for Nuclear Science Outreach: *Implementation*

- Creation by the DOE and the NSF with sufficient resources, either at a university or a national laboratory
- Acquire a professional and dedicated staff knowledgeable about nuclear science; K-12 and public education; and public relations
- Achieve nuclear science community input and feedback by the establishment of ties with the DNP, its Committee on Education, and the Division of Nuclear Chemistry and Technology of the ACS

Center for Nuclear Science Outreach: *Some of the Goals*

- To cooperate with appropriate existing outreach efforts while retaining a dedicated national focus and a unique and independent character
- To enhance educational materials in nuclear science targeted toward teachers, students and the general public (CDs, DVDs, pamphlets, etc.)
- To create an effective, centralized nuclear science website for K-12 students and teachers
- To develop materials to motivate the interest of students at all levels in nuclear science
- To stimulate involvement and outreach by every active nuclear scientist
- To accomplish its mission by careful selection among these goals and others (see the report), followed by dedicated and consistent efforts

The End

Our report was unanimously accepted by the Nuclear Science Advisory Committee and submitted to DOE and NSF in December 2004.

If you would like a pdf version of the report, please e-mail me at jcerny@berkeley.edu